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IMPLICATIONS OF INTERNATIONAL COMPARISONS OF ENERGY USE: THE SWEDISH/AMERICAN CASE REVIEWED

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Abstract

The Comparison of Swedish and U.S. energy use is reviewed. It is seen that more efficient energy use in Sweden accounts for much of the difference in overall energy use observed. Some historical policies are discussed, particularly differences in energy pricing. The record since 1973 is reviewed, and signs of conservation in both countries are found. some specific areas, such as tight houses, district heating, and lifestyle are reviewed; both countries offer lessons in conservation. Finally, a comparison of some key policy elements is offered.

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I. Introduction

The shock of the oil embargo heightened interest among countries to examine each other's energy use, with the goal of both understanding differences and possibly discovering interesting energy conservation technologies. In 1975, I began a comparison of the U. S. and Sweden, two countries that exhibited important similarities in enough areas to make the comparison credible. The present work summarizes that initial comparison*, extends it, and offers in addition a discussion of what has taken place in each country, relevant to the comparison, since 1972. While Sweden and the United States have narrowed their energy differences somewhat since 1972, the difference in efficiency still account for the bulk of the lower Swedish energy use, relative to activity.

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*For further reading, see Schipper, L. and A. Lichtenberg, Science 194, 3 Dec. 1976 (Energy Use and Well Being: The Swedish Example), and L. Schipper in J. Sawhill, ed, Energy Conservation and Public Policy, Report of the 55th annual American Assembly, Prentice Hall Books, 1979 (Energy Use and Conservation in Industrialized Countries). These works contain the predominant references for the present discussion. References to new material will be given in the bibliography herein.

II. Meaning of Conservation

The meaning of conservation is often ignored or undetermined in studies. For our purposes (see Schipper and Darmstadter, 1978), energy conservation means reducing the cost of using energy with other resources by

a) substituting less costly inputs, notably capital, for energy
b) altering behavior in the short run (miles driven, indoor temperature) or
c) gradually altering lifestyles or economic structure (living near work, owning fewer cars, producing less raw steel).

The principal driving force behind conservation is the increased direct and social cost of energy. This definition is consistent with traditional economic thought (Schipper 1979a).

The definition advanced has an important meaning in international discussions. The effect of great variation in income upon energy use (through ownership of equipment) is not considered part of conservation. Nor is the increase in energy use in less developed countries associated with rapid rise in incomes "anti-conservation."

III. The United States and Sweden Compared

1. General Considerations

In summarizing the U.S.-Swedish comparison we will, whereever possible, breakdown differences in energy use according ot the scheme suggested in the discussion of conservation, separating effects of economic structure, lifestyle, and energy intensity. The reason for this breakdown follows from the discussion of conservation: higher energy costs will stimulate short term reductions in indoor temperature that may persist, but more important middle term changes in building practices, including addition of insulation to existing homes. This second action reduces the energy requirements of a unit of indoor thermal comfort, possibly by a great amount. In the long run, very high heating costs might affect the size of dwellings or the choice between single and multiple family dwellings, that is, the economic structure of the habitat sector. This breakdown allows the analyst to find those differences in energy use among countries that may suggest immediate conservation measures--mostly technical--that have little political or social impact on peoples' lives.

2. Contrasts in Energy Use

The greatest differences in energy use appear in the intensities (or efficiencies) of use for process heating, space heating, and transportation. To display the overall effects of both intensity and mix of output, these relative quantities (For Sweden and the U.S.) are displayed in Table 1. (Detailed Tables are found in Schipper and Lichtenberg.) As can be seen, space heating in Sweden is remarkably less intensive than in the U.S., when measured in Btu/square meter/degree-day. Other studies suggest that Scandinavia is unique in this area. The living space per capita is nearly as large in Sweden as in the U.S., while most of Europe falls behind these countries in this important measure of living standards. The energy intensity of apartment heating in Sweden is nearly as great as that in single-family dwellings (see below). This means that the relative efficiency of space heating in Sweden vis a vis the U.S. cannot be ascribed to the greater proportion of apartments there compared with the U.S.

On the other hand, households in Sweden generally have smaller appliances than in the U.S., reflecting a different lifestyle and lower aftertax incomes, and this results in a somewhat lower household use of electricity. But residential electricity use in Sweden has continued to climb since 1973, narrowing the gap. Electric auto-seat warmers and other gadgets are popular, while refrigerators and freezers increase in size and use.

Indoor temperatures in Sweden are higher than in the U.S. One relative inefficiency in the use of heating and hot water occurs in Sweden because of common metering and unregulated hot water and heating systems. This leads to a surprisingly large consumption of fuels for heating in apartments, although the overall use of heating is more efficient in Sweden than in the U.S. because building shells are well constructed.

In the industrial sector, the differences in intensity are consistent with the results of other studies. Sweden is neither the most nor the least efficient country in Europe. The overall Swedish mix in manufacturing is weighted more heavily towards energy-intensive products than is the case in the U.S, but energy intensities in Sweden are generally lower, because of higher energy prices there.

A great contrast is found in transportation, dominated in both countries by the auto. Swedes travel only 60% as much as Americans and use 60% as much fuel per passenger mile. This held Swedish gasoline use in the early 70's to 1/3 of America's. Mass transit and intercity rail are less energy intensive and more widely used in Sweden, while air travel is overwhelmingly larger in the U.S. Intra-city trucking in Sweden is considerably less energy intensive than in the U.S., but long haul trucks in Sweden use slightly <u>more</u> energy/ton-mile than in the U.S. The greater distances in the U.S. mean that ton-mileages (at distances greater than 30 miles) are far greater there. The overall U.S. long haul mix is less energy intensive but total use is greater because of distance. Here is a clear example of how greater <u>use</u>, on the part of the U.S., has little to do with inefficiency. In fact, the American freight machine is more weighted to less energy-intensive railroads than in most other countries.

Although the impression that Sweden is somehow "energy wise" and the U.S. less so is unavoidable, the real lesson from this two-country comparison is that energy use for important tasks is flexible, given time, technology, economic stimulus and, in some cases, favorable government or institutional policies. Indeed Sweden could be using more energy than the U.S. per capita (or per unit of GNP) and still be more efficient, (as is the case in manufacturing) or the converse.

3. Policies and Prices

What were the major historical energy policy differences between Sweden and the U.S.? These may explain the differences outlined above: Sweden always had an electrical policy, but coal and then oil were imported as necessary to meet rising demand. Sweden taxed motor fuels heavily, but for fiscal, not energy purposes. In the housing sector, cold climate made energy consciousness a must, however, as reflected in progressively tighter building practices. In all (see Lonnroth et al, 1977) Sweden had energy policies but little energy use policy.

The same was true for the United States (Stobaugh and Yergin, 1979). Little attention was paid to energy demand, certainly due in no small part to ample, low cost domestic supplies. The helter-skelter energy properties of the building stock, particularly homes (Schipper, 1979a) suggest a situation far from economic effectiveness even in the days of relatively cheap energy. Thus, in both Sweden and the U.S. the demand for energy pre-1973, while certainly a function of many non-energy policies or ad hoc supply policies, was not formed directly by an overall energy policy.

Historically, higher energy prices in Sweden than in the U.S. are an important factor that has led to the more efficient energy use in that country. While pre-embargo oil prices in both the U.S. and Sweden were roughly equal (Table 4), Americans enjoyed natural gas and coal resources that provide heat at 20-50% lower cost compared to oil. In the case of electricity, the two countries were radically different (up to 1972). Since 75% of all electricity generated in Sweden was produced by hydropower, the ratio of the cost of electricity to the cost of heat from fuel was only half as great in Sweden as in the U.S. Industry in Sweden naturally developed a more electric-intensive technology base. However, 30% of thermal electricity generation in Sweden was accomplished through combined production of useful heat and electricity in industries or in communities, the latter systems providing district heat. Consequently, in Sweden, only about 7,000 Btu of fuel were required (in 1971-72) for the thermal generation of a kilowatt hour of electricity. Increases in the cost of nuclear electricity and oil favor the continued expansion of combined generation, but institutional problems have slowed that expansion in the late 70's.

An example of the effect of different prices helps explain Swedish energy use. In Sweden, autos are taxed in proportion to weight, both as new cars and through yearly registration. Swedes found a loophole, the registration of autos through companies, but the government discovered this trick and raised the tax on company owned cars.

Gasoline is taxed, the amount recently being raised to 90 cents per U.S. gallon, vs. less than 15 cents in most of the United States. Even still, Sweden has relatively low priced gasoline compared with France or Italy. But overall high prices, compared to the U.S., restrain total auto use, especially in short trips and in cities.

IV. The Post-Embargo Record

While little careful analysis of the post embargo period has been attempted, some data available now indicate progress towards more effective energy use, especially in the U.S. Table 3 gives a few important indicators for the U.S. and Sweden.

In Sweden, grants and loans have been handed out extensively (the order of 10^9 U.S. $) for industrial and building improvements and innovation. While the Starre Report (Starre 1979) shows disappointing results from the effect of the program alone on buildings (far less energy saved per unit investment than planned), the industrial program (SIND 1979) shows remarkable results, bring about a 2 percent savings in total industrial oil/electricity use at cost of less that $12 U.S/barrel equivalent sound. However, both these programs complement the spontaneous improvement in efficiency stimulated by higher prices.

In Sweden the "spontaneous" observations are somewhat different. Autos grew in average size until 1977, and their numbers continued to rise at around 3%/year. While industrial conservation projects show some startling successes (see SIND, 1979), the sluggish economy, not recovered until 1978, prevented the major users (paper and pulp, steel) from maintaining the high capacity necessary to achieve energy efficiencies with existing plants. Hoped-for expansion in industrial cogeneration has been slowed as well.

In the residential sector results have also been mixed. While some data show a small reduction in oil use per home (Table 3), there has been steady increases in electric heating (using more resource (primary) energy than oil) and in electric heat use per house. And residential non-heat electricity use is still growing much faster than in the U.S. Finally, electricity use in commercial buildings also grew in the 1972-77 period. However, rates of growth in Sweden have slowed somewhat since 1973.

Thus, it is primarily structural changes growth in auto fleet, new home size, appliance use, that have pushed up gasoline and electric use. Indeed, most consumer energy prices (in real terms) in Sweden (Table 4) remained near their 1974 high through late 1978. No wonder the frustration in Stockholm at the lack of success in the consumer sector! However, an intensive campaign in 1979 brought about a 7 percent savings in oil heating in late winter. Finally, it should be noted that new Swedish homes have 40 percent less heat losses than existing stock, and already improvement on these new homes are expected (see BECA, 1979 for a compilation). This is seen in Fig. 1.

In the U.S., where nearly every energy intensity was greater than in Sweden, progress has been dramatic, as Table 3 shows. While the prices of energy have moved in conflicting ways (Table 4) all observers now expect that prices will rise steadily However, major conservation programs were limited to relatively few (Hyman and Saltonstall 1977, Schipper et al 1979).

- o Mandatory Improvement in Auto Fuel Economy
- o Development of Building and Appliance standards (but promulgation in only a few states as of 1979)
- o Various local or national tax credits for residential conservation or renewable energy.

What has certainly hampered conservation in the U.S. has been low fuel prices, at least on a world scale. But given time, both countries look promising - in fact, Sweden and the U.S. seem to teach us an important principle:

> Rising energy prices, coupled with limited intervention (i.e., building standard, some financial incentives, and above all time), seem necessary and sufficient to bring about massive conservation overtime, in response to tightening energy supplies.

The reason for this somewhat startling conclusion is that only six years have passed since the events of late 1973, a time far too short to replace most energy using equipment, yet two of the wealthiest economies in the world have been able to conserve roughly 10-15% of energy use, relative to pre-1973 trends in energy intensity and economic activity.

V. Some Lessons from this Comparison

a. Buildings

Relative to other nations, the Scandinavians display enviable practices in the buildings sector. Energy use per unit of area per unit of climate, the best measure of efficiency, is truly less than in Central Europe or the United States. Figure 1 shows this dramatically. Moreover, the heat losses through walls or other components have declined steadily, in part as building codes improve. Figure 2 shows the improvement for walls.

Scandinavian home building practices make it clear that heating needs can be cut considerably in the United States by as much as 80% compared with pre-1973 homes. While insulation of existing homes in the U.S. is the most popularly cited need, control of infiltration and ventilation may make an even larger contribution to saving energy profitably, when existing or new Swedish buildings are compared with untight U.S. structures. Experience in the building research programs at the Center for Environmental Studies, Princeton, and the Lawrence Berkeley Lab suggests that one can achieve the low air infiltration rates now called for in Swedish building codes (considerably less than 1 air change per hour in homes).

One effect of careful insulation and tightening of structures is the increase in comfort that goes beyond the relief of a lower heating bill. When structures are carefully controlled, the heat comes on less, causing less air exchange and heating up of the indoors near vents. Drafts are reduced. The temperature difference between floor and ceiling, between areas near windows and inner parts of rooms is reduced, reducing both air motion and discomfort. Indeed it has been suggested that Swedish homes are build so well in order to satisfy desires for comfort ahead of simply saving energy.

It has become clear that infiltration losses in homes can be reduced so far that odors, indoor pollution including evaporated plastics, radon gas from building materials, cigarette smoke, can become a nuisance or even a true health hazard. Forcing ventilation by fans and ducts has been a common practice in Swedish homes. The exhaust air contains valuable heat, however, and an inexpensive heat exchanger could recover much of the heat while allowing the unpleasant pollutants to be exhausted before they could build up in the home. In new Swedish apartment buildings, where the heat content of exhaust air is enormous, heat exchangers can be required, an attractive possibility for centrally heated and ventilated U.S. buildings. It should be noted that heat recovery is extremely important in the U.S. in warm months, when cooling from exhaust air can be recovered in the system.

b. District Heating

One technology suggested by the Swedish experience is district heating, by which blocks (or square kilometers) are provided with water-born heat (and hot water) from central plants. How does district heating save energy? Heat-only systems produce hot water in well maintained high temperature boilers whose heat transfer from fuel to water is significantly higher than in individual boilers, more than offsetting the relatively small (<10%) losses in transmission of water. In the ideal case, the largest possible fraction of hot water is made in conjunction with electric power. Heat that would have been rejected to the environment is now used to heat buildings, the extra amount of energy added to this water (or alternatively the electric power sacrificed) typically 5-8 times less than the useful heat produced. Alternatively, DH can be described as a system that produces electricity for far smaller losses than in condensing-only power plants. Energy savings equal the extra fuel required were electricity and heat made separately. Exactly how large a fraction of all district heat is produced with electricity depends on the characteristics of the heating season (or need for cooling) as well as the electric power demand characteristics and existing power plant mix. DH economics depend both on this accounting and critically on capital cost of distribution, which in turn is very dependent upon the amount of heat sold per square km. In dense areas with long heating seasons, such as cities in Scandinavia, DH provides low cost heat.

Other important advantages accrue to cities with DH. Pollution from burning oil is clearly reduced because controls are better than in separate boilers. This advantage was important in starting up such systems in Sweden in the days when oil was cheaper. Moreover, oil-fired DH systems run on cheap heavy oil. Additionally, DH centrals can run on a variety of fuels, including wood or coal, and can be built to switch rapidly. Since the combustion operation is centralized congestion associated with delivery of fuel is minimized.

Finally, DH relieves individual building owners or occupants from worrying about heating, and reliability is good.

Whether DH is economic for the U.S., however, or other regions in less than the coldest climates, is questionable. When comparisons are made of DH economics in Europe or the U.S. and Scandinavia, the heating load that enters in the calculation is often assumed at today's levels, rather than calculated based upon conservation that would be appropriate at the price charged for DH. Swedish figures for heat demand are bloated by the lack of individual meters. The real cost of DH may be unknown since the unit price is so sensitive to the number of units over which the enormous fixed costs are spread. If DH can provide cooling, of course, the economics change considerably since such cooling reduces electric peak loads and reduces waste heat loading in the summer in cities. Certainly technical studies and actual implementation, as has been discussed for cities in Minnesota and other colder states, are important. At present, it appears that it is far cheaper to save fuel by end use reduction than by DH, at least in most of the U.S.

However, the real problems for DH in the U.S. may be institutional. Sweden has contemplated mandatory hook-up as a means of insuring high density and thereby lowest costs. Land use planning with long time horizons, far more prevalent and accepted in Sweden, is essential to the orderly build-up of a system over a decade. Moreover, DH has penetrated principally apartment areas. In Västerås, Sweden, where virtually all single and multiple family dwellings receive district heat, unit costs for detached houses were two to four times greater than apartments, because of higher distribution costs. In the U.S., detached houses dominate and little high density new construction is on the horizon. DH may not fit into American living patterns except in existing downtown areas, possibly with urban renewal.

Will Scandinavian DH systems be important in the U.S.? Unfortunately, many of the advantages appear only indirectly and not as direct cost reductions, especially when conservation reduces heat needs so much in most of the U.S. And DH can only appear as a result of coordinated action, with government present at nearly every stage. Indeed it has been argued that DH has been attractive in many places previsely as an extension of municipal power into the service of comfort. But struggles over nearly every recent government energy effort does not speak well for DH.

Thus, DH faces institutional tangles that may only be worth overcoming in areas like Minnesota, where the potential benefits are inarguably great. Smaller ventures, such as time-of-day pricing and individual metering of apartments or large scale retrofit insulation programs ought to be tried first before any large scale DH is promoted on a national scale. For ultimately the energy saved/unit investment should be far higher with simpler schemes than district heating.

c. Transportation

In transportation the lessons for the U.S. are ones of a sensitive policy nature. The difficulty in dealing with transportation, as incomes rise and autos become more important, is clear: autos are popular. Obviously, one cannot "hold back" the auto in the U.S. or elsewhere without offering attractive alternatives.

Because of low gasoline prices, tax subsidies for owning single family dwellings, little or no land-use planning, and easy access to freeways, people are spread out, and mass transit in America seems hardput to capture all but a small fraction of land passenger miles. The decline of mass transit's share of passenger miles in Europe, very much similar to what was seen in the U.S. 20-40 years ago, emphasizes this even more clearly. As usual, this decline in the mass transit share of traffic happens because the auto increases its absolute role in traffic. New owners, new patterns of commuting, new uses of the auto for vacations have become as abundant in Europe as in America in the last war era. Thus, auto miles have increased tenfold in Sweden since 1950, and similar increases have occurred everywhere in Europe (see Table 5).

Herein lies an important point worth considering: what will be the ultimate level of auto ownership, miles driven, and efficiency in Europe (and the developing countries, for that matter), relative to the U.S., where miles per gallon is now increasing and ownership all but saturated (see again Table 5)? The experience of Sweden over the past decade - rapid increase in ownership, slight increase in auto weight, decline in miles-per-gallon - does not hold well for the countries in Europe that have not even achieved one car per three inhabitants. Yet all governments must at some point confront the future role of the automobile and associated problems of land use, lest increases in the use of gasoline frustrate desire for lessening of oil imports.

d. Lifestyle

While the original study avoided treating lifestyle explicitly, it is clear that this factor does enter into explaining differences in energy use patterns among countries. For the energy conservation planner wary of establishing normative conservation goals or standards, the issue of lifestyle may be unwelcome. Nevertheless, it is important to use our observations of other countries in an attempt to understand the possible couplings between energy, conservation and lifestyle.

Quantitatively there are two aspects of lifestyle that bear directly on energy use: the mix of non-energy goods and services, demanded by consumers, and the mix of key energy intensive activities that interact directly with energy. To the latter group belong central heat and high indoor temperatures, patterns of auto ownership and use, land use patterns, appliance ownership, vacation and travel habits, and ownership of second homes or boats. The U.S., Canada, and Sweden tend to have the greatest energy demands arising from these patterns, while the remainder of Europe, while considerably "behind", is narrowing the difference somewhat.

It is hard to label activities such as living far from work as "wasteful", yet it is important to investigate why people live and work where they do, why they may evacuate cities on weekends for summer homes, why they prefer detached single family dwellings to apartments. For example, most countries allow homeowners to deduct mortgage interest payments from taxes, an important subsidy for home-owning, especially in high tax countries like Sweden. Moreover, commuters in Sweden can deduct the cost of the monthly bus pass from income, and those who can prove that driving saves 45 minutes per hour (each way) compared to mass transit can also deduct the full cost of driving. These "lifestyles" subsidies may be justified on social grounds, but they have a measurable impact on spreading out, which in turn tends to increase energy use.

Should any country "embrace" another country's lifestyle for the sake of saving energy? Probably not. However important the connection between lifestyle and energy, there are so many conservation opportunities that involve technology or minimal behavioral adaptation to higher energy costs that we may not need to consciously live like other peoples just to save energy. However, understanding the energy implications of alternative patterns of consumption, location and occupation certainly would illuminate options for society. Thus, the energy comparison of Mora, Sweden and New Ulm, Minnesota created great interest in trying to quantify the energy implications of perceived differences in lifestyles in the two countries. In this case the market-basket differences probably have less to do with observed differences in energy use than the lifestyle (or technical) differences in direct consumption habits.

While little data yet exists that allows general conclusions to be made about energy and lifestyle, details from the Swedish-American comparison and other work support some important tentative findings:

* The greatest differences in driving habits arise in the use of the auto for short trips, far more prominent in the U.S.. Commuting via auto is gaining, however, in Sweden, and load factors are low, partly because people living in clustered areas are still riding mass transit. Greater distances in the U.S. affect distance to work, but do not account for the significantly greater distances travelled. Indeed, distance per car per year (Table 5) varies far less across countries, suggesting that it is the ownership of a car that sets off lifestyle changes leading to increased driving nationally.
* Land use planning influences lifestyles and energy use considerably. As people spread out into suburbs, often aided by government home-building subsidies, cars become a vital link to shopping and services. Still, zoning in Sweden allows some services to be "built in" to residential areas, while in the U.S. the great suburbs seem to isolate residences from services.
* The low relative cost of scheduled air flights in the U.S., compared to Europe, offers an energy-intensive but time-saving alternative to auto vacation travel. In Sweden low cost charters have gained immensely in popularity, but in most places the auto seems to dominate vacation travel, causing immense traffic problems never seen in this country. Additional studies

should be made to compare patterns and costs of auto use in Sweden and the U.S. Rail travel is still important for vacationing and even much intercity business travel in Sweden, because of high density. A new system of reduced prices was introduced with immediate success in June, 1979.

* Other lifestyle aspects of living patterns remain to be understood vis a vis energy use. For example, what is the overall impact of commuting to second homes in countries like Sweden?# Does Americans' moving every six years (on the average) inhibit the ability to design communities and residences for long range resource costs?

Quantitatively it is possible to separate effects of life-style from energy comparisons by concentrating n the use of heating, autos, and appliances. Whether lifestyles directly affect the intensities of devices, which can be affected by policies and prices, is unknown. In any case we know that lifestyles do affect energy use, and we know that these structural effects are apparent in a few important areas. This accounts for some of the differences in energy use between North America and Scandinavia. Since conservation affects mainly intensities we can safely say that a great deal of conservation can be decoupled from lifestyle issues, while further reductions in overall energy use might come about through key lifestyle changes in the U.S. Whether these changes themselves would occur is another matter worth discussion elsewhere.

A study by Fredbäck (Fredbäck 1979) suggests this cannot be ignored.

e. The Carrot or the Stick?

As a final consideration, we consider how best to stimulate or insure the economic use of energy. We noted above that a combination of policies, including allowing enerrgy prices to rise to world levels, appears necessary, but there is little talk of long-term restrictions on behavior or economic structure as a means of achieving energy economies, though there is some speculation in Sweden along these lines in the study of phasing out nuclear power. (Konsekvens Utredning, 1979).

In Sweden, pricing policies have included taxes that try to incorporate perceived social losts into energy prices. Thus, the cost of strategic oil storage is borne by oil users through a tax; the perceived fears of too rapid expansion of nuclear power appear as a tax on electricity. The well established welfare system handles the burden of high costs on the less-than-well to do. A growing problem users; private use of business-registered (and thus, income 'tax free') motor vehicles, amounting to nearly half of new auto sales in 1976, was caught in 1977 through tax reform.

But low electricity prices appear to persist (SOU, 1978), and a majority of Swedes still do not pay directly for their heat. On the other hand, the firms that administer apartments have taken steps to improve energy use anyway. Overall, some reforms in Sweden are called for (SOU 78, 1978).

In the U.S., prices are rising and attitudes are changing. But there was little interest in taxing domestic fuels to the world prices, as witnessed by the defeat of Pres. Carter's Crude Oil Equalization tax. That is, for all the talk of the high social cost of importing oil, there seems to be few willing to face, let alone pay that cost.

In Sweden the State has subsidized conservation. The reasoning is simple - those measures whose rates of return are accetable to society but too low for individuals or firms are supported. In the U.S. there has been little direct subsidy to conservaton. President Carter's July 16, 1979 address reversed a policy set down in the 1978 National Conservation Policy Act (see Schipper, et al 1979) by inviting, if not forcing, energy suppliers to provide conservation capital as long as the rate of return (or alternatively amortized cost of energy saved) exceeds (falls below) that of new energy supplies. In Sweden such activity is limited to services of oil distributors. That is, the U.S. approach may ultimately reach out to touch every existing building, in contract with the more passive Swedish approach.

The comparison shows is that in the industrial sector energy prices have been an important consideration in the choice and energy intensity of equipment; a certain influence over the size of autos and to a lesser extent the use of the alternative, mass transit; a consideration in the construction of buildings, and to a lesser extent an influence on heating habits.

Moreover, the consensus of high level studies in both countries (CONAES, SOU-78) is that future energy needs, per unit of activity, will fall considerably due to rising prices, increased awareness, and new techniques for achieving even greater energy economies. Indeed, one should not point to the already envious position of Swedish housing, as evidence of little remaining conservation potential. Fig. 1 shows for a variety of climates in the U. S. and Sweden the average heat consumption for all homes, and consumption (measured or predicted) for particular samples. The large number of Swedish homes well under the standard argues for great potential. The low figures are matched by model studies for the U. S. (shown as "LBL Low-infiltration Optima").

In the U. S. work is well underway towards these goals through the promulgation of Building Energy Performance Standards (BEPS), by which the gross energy consumption per square meter of a home or building is regulated; the means for achieving this goal is understood but not prescribed. In Sweden, standards in effect since 1976 (SBN 1975) appear to effect about a 40% reduction in energy use in single family dwellings. While BEPS are based explicitly on energy prices, climate the cost of each measure and the interest rate, SBN 75 appears to count only climate explicitly. That fuel and electric heat prices have finally begun to rise again in Sweden has not yet caused pressure for re-evaluation of standards, though designs of many new homes far exceed the performance of thos built to SBN 75.

Here lies an important difference in approach. In Sweden SBN 75, developed by Statens Planverk, was cast in final form after much internal negotiation ("remissyttrande"). In the U. S. the political process is much slower, in part because the ultimate standards must appear to meet cost-effectiveness in order to survive the unavoidable hearings and compromises at the local level. Moreover, building permits are much more a local affair in the U. S.; the federal government would have to threaten to end the FDIC insurance or FHA Home Loan Program in order to "force" a state to adopt the BEPS standards worked out for that state's climate and prices. But the building industry in Sweden appears to have supported tightened standards, as has the engineering industry. By contrast there has been much dissent among interested parties in the U. S. since the first Oil Embargo. In Sweden adversaries commonly assemble under one roof to arrive at consensus ("samförstående") while in the U. S. dissent for its own sake seems to rise to prominence. The result of these differences, in my view, is a strong (but not perfect) code in Sweden with evidence of enthusiastic compliance, on the one hand, versus the possibility in the U.S. of a very strong code — or, equally likely, a weak code — whose future rests on the uncertain politics of dissent.

There is furthermore a difference in attitude about the economics of the building sector. In Sweden speculative building and real estate speculation in particular, plays a very minor role in the shaping of communities and structures. Many Swedish homes are financed over 60 years, and moving is far less frequent. In the U. S., by contrast, building is often an object of investment. Life-cycle costs, long run quality control appear to be less important in part because people move more often than in Sweden. As a consequence there seems to be less of a rush by the industry or the buyer to find energy conservative money saving housing, though data from the U. S. National Association of Home Builders do show that homes built today are far more energy fit than those built 10 years ago.

Sweden has required local energy plans that encompass not only improvement in municipal facilities, but consideration of energy in land use questions and efforts at consumer education and retrofit. In the U. S. these activities -- education and retrofit -- do occur, but largely in response to market forces alone or to initiatives of utilities, most of whom are forced by public utility commissions to encourage or even pay for conservation. Here the adversary nature of U. S. politics plays a central role; utility commissions, mistrustful of utilities, flexed their authority in a direction that could save rate payers billions of dollars. In Sweden, the lack of aggressive political adversity seems to allow for a more passive conservation. Lots of funds available, but little marketing accompanies these and everything seems left to good faith, resulting in over-investment in the least productive energy saving options (see the Starre report). Consumer or environmental groups have been nowhere active in pushing for tighter standards or better retrofit in Sweden, while in the U. S. political pressures from these groups have been important in getting Congress and two presidents both to pay attention to conservation and to finance part of the effort publically. Still, in early 1980 Sweden has expended far more public money *per capita* than the U. S., but the

U. S. appears to have reduced space heating and appliance energy intensity more. This confusing situation is perhaps too fresh for any more definitive analysis. But it is clear that ongoing comparisons of the two approaches will reveal many of the advantages and pitfalls of different paths to conservation of residential energy use.

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TABLES AND APPENDIX

Table 1. Sweden/U.S. contrasts in energy use; ratios are listed (Basis: 1970-72).

		Per capita demand	Intensity	Total energy use	Notes
Autos		0.6	0.6	0.36	Swedish 24 M.P.G. driving cucle uses less energy
Mass transit trains, bus		2.9	0.80	2.35	Mass transit takes 40% of passenger miles in trips under 20 km in Sweden
Urban truck		0.95	0.3	0.28	Swedish trucks smaller, more diesels
Residential space heat (energy/deg day/area)		1.7 0.95	0.5	0.81	Sweden 4200 deg days C vs 2900 U.S. deg. days
Appliances		?	?	0.55	U.S. More, larger appliances
Commercial total/sq ft		1.3	0.6	0.78	Air conditioning important in U.S. only
Heavy industry (physical basis)	Paper Steel Oil Cement Aluminum Chemicals	4.2 1.1 0.5 1.35 0.5 0.6	0.6-0.9		Sweden more electric intensive due to cheap hydroelectric power. Also, Swedish congeneration
Light industry ($V.A.)		0.67	0.6	0.4	Space heating significant in Sweden
Thermal generation of electricity		0.3	0.75	0.23	Swedish large hydroelectric, cogeneration

Table 1 allows a decomposition of the various elements of per capita energy demand into structure factors (first column), and intensity factors. In each case, the ratio of Swedish to U.S. Demand, intensity, or total consumption is given By using this scheme, direct comparisions of GNP, market basket in the aggregate, or the true exchange rate are avoided. The actual figures are given in some detail in Schipper and Lichtenberg. For residential space heat, the structural factor is broken down as differences in degree days and differences in area/capita. The structural effect of plentiful hydro power in Sweden is seen as the low ratio of demand for thermally produced electricity; the effect of cogeneration is seen as the low ratio of fuel/kWh produced.

Since 1972 (see below, Table 3), the most important changes have been in the per capita demand for autos, residential area/capita in Sweden (all up), appliances and industrial, and residential space heating intensity in the U.S. (all down).

Table 2. Typical energy prices in the U.S. and Sweden. Exchange rate used is $1 = 5.18 skr 1960-1970) and 4.30 skr (1974). Data sources listed in Schipper and Lichtenberg.

	U.S.				Sweden			
	1960	1970	1974	¢/kWh 1970	1960	1970	1974	¢/kWh (1970)
Oil Products (¢/gal):								
Gasoline	30	35	45	1.04	53	61	116	1.82
Diesel	23	28	35	0.83	42	48.8	90	1.45
Heating oil -								
Small customers	15	18	35	0.50	13.3	13.2	40.6	0.37
Large customers	10.5	12	25	0.33	13.3	13.2	40.6	0.37
Heavy oil	7	8	23	0.23	7	8.5	22.5	0.24
Gas (¢/MM Btu):								
Residential	82	87	113	0.29	—	550	680	1.9
Industrial								
Firm service	51	50	—	0.17	—	—		
Interruptable service	33	34	—	0.11	—	—		(
Coal, Industrial								
($/ton):	10	13	25	0.14	—	18		0.2
Electricity (¢/kWh):								
Base	2.75	2.75	—	2.75	3.14	2.12	2.3	—
Base and space heating	1.75	2.0	—	1.5	—	1.5	2.0	
Industrial	1	1	1.5	(0.4-2.1)	—	0.93	1.8	(0.6-2.2)

Table 3.

Sweden, United States
1972 - 77
Energy Indicators:

	U.S.	SWEDEN
Autos/Capita	10%	16%
Miles/Gallon	3%	5%
Gasoline/Car/Yr.	-7%	+5%
Oil or gas heat/house	- 10-15%	-8%
Electric heat/house	0%	+5%
Appliance Electricity/house	+(5 - 10%)	+ 30 - 40%
* Energy per Unit Output	-17%	-2%
Unit	(Value added)	(Shipments)

These are complied from various sources to show relative changes in each country. Industry data in Sweden affected by low capacity in 1977, residential includes about 3% increase in average dwelling size. Heat is approximately climate corrected. U.S. Sources include Monthly Energy Review, U.S. Dept. of Energy, Energy Information Administration, July 1979; Am. Gas Association; Atlantic Richfield Oil Co., Oak Ridge National Lab; Swedish sources include Statens IndustriVerk (SIND), SIND 1977:9 and Pm 1979:1; Energi (Bilagdel Energibehov foer bebyggelse), Dept. of Industry, 1978; Electricity Supply and Use tables from Statistical Central Bureau.

Table 4.

Some Energy Indicators
Real Prices 1973 - 1977
(Percent Change)

	U.S.	SWEDEN
Residential Electricity		
Non Heating	+20%	-4%
Heating	+34%	+6% (74-77)
Heating Oil	+30-40%	+45%
Heating Gas	+45%	---
Gasoline	+18% (73-78)	+3%

Sources: U.S. - U.S. Department of Energy, Monthly Energy Review, July 1979; Typical Electrical Bills: All Electric Homes, U.S. Department of Energy, Energy Information Administration, October, 1978.

Sweden, Statens Pris och Kartellaemd, Stockholm (State Price Board); Swedish Esso, "Oljeaaret i Siffror" 1972-79; Svenska Elverksfoereningen, yearly reports.

Table 5. Passenger transportation: 1972

	Pass-Mi/Cap land travel	MI/auto	% Auto	Energy/Cap MwH Cap	Intensity KWh/pass-mi	Gas price (US = 100)	% of Income	Auto ownership, cars per 1000 people	
								1961	1972
United States	11,300	10,000	92	9.4	.90	100	3.4	344	462
Sweden	6,280	8,900	84	(3.8)	(.60)	(180)	(0.8)	173	303
Canada	6,550	10,000	88	6.3	1.1	(110)	----	237	377
France	3,980	----	77	2.2	.71	256	0.7	133	269
W. Germany	5,870	8,900	82	2.4	.51	243	1.1	92	253
Italy	4,160	7,610	80	2.2	.65	348	0.6	48	229
Netherlands	4,620	10,000	81	2.2	.59	---	---	53	229
United Kingdom	4,990	8,950	80	2.0	.49	192	1.1	113	230
Japan	3,760	----	34	0.9	.74	250	0.2	7	119
Europe avg.	4,840		80	2.3	.60	----	---		

Source: RFF; IEA; Swedish data modified by Schipper and Lichtenberg; Prices for gasoline, income shares from RFF; distance/auto/yr from WAES.

Passenger transportation: Shown are the total miles, the share taken by autos, the resulting per capita energy consumption, the intensity in kwh/passenger mile, the gasoline price relative to the U. S., and the percentage of income spent on driving. Finally, auto ownership figures for 1961 and 1972 are shown, displaying the rapid growth in Europe and Japan that still lies far from saturation.

Figure Captions

Figure 1. Building Energy Compilation and Analysis. Heating use per 100 m^2 per celsius degree day is plotted on the vertical axis against climate (in degree days) on the horizontal axis. The lines indicated averages for existing U.S. dwellings in 1970, the proposed Building energy performance standards according to Lawrence Berkeley Lab simulations (1979(, and an estimation using very low air exchange as found now in Sweden. The average of French centrally heated houses is FR77, as well as an estimation of the results of the 1974 French building code, FR74. The Swedish stock is shown as SW 72, the estimated heat losses due to the new code, as SW SBN 75. Also shown one measurements from Sweden, and simulations of designs for Smaalands Taberg by Bengt Hidemark and Bo Adamson (SW 79-2 and 79-3). Low energy houses in Scotland (SC 76 and 77) are also shown. The dollar and percentage figures give estimates of the cost of reducing consumption a shown amount. Details are contained in BECA 1979. Electric homes are adjusted to reflect a nominal 65% fuel heater efficiency. The figure shows both the variation in energy use with climate and the gains to be achieved by tightening practices. Present U.S. building practices in new homes lie somewhere between "stock" and "LBL OPt medium infiltration" (infiltration means involuntary leaking of cold air into the house).

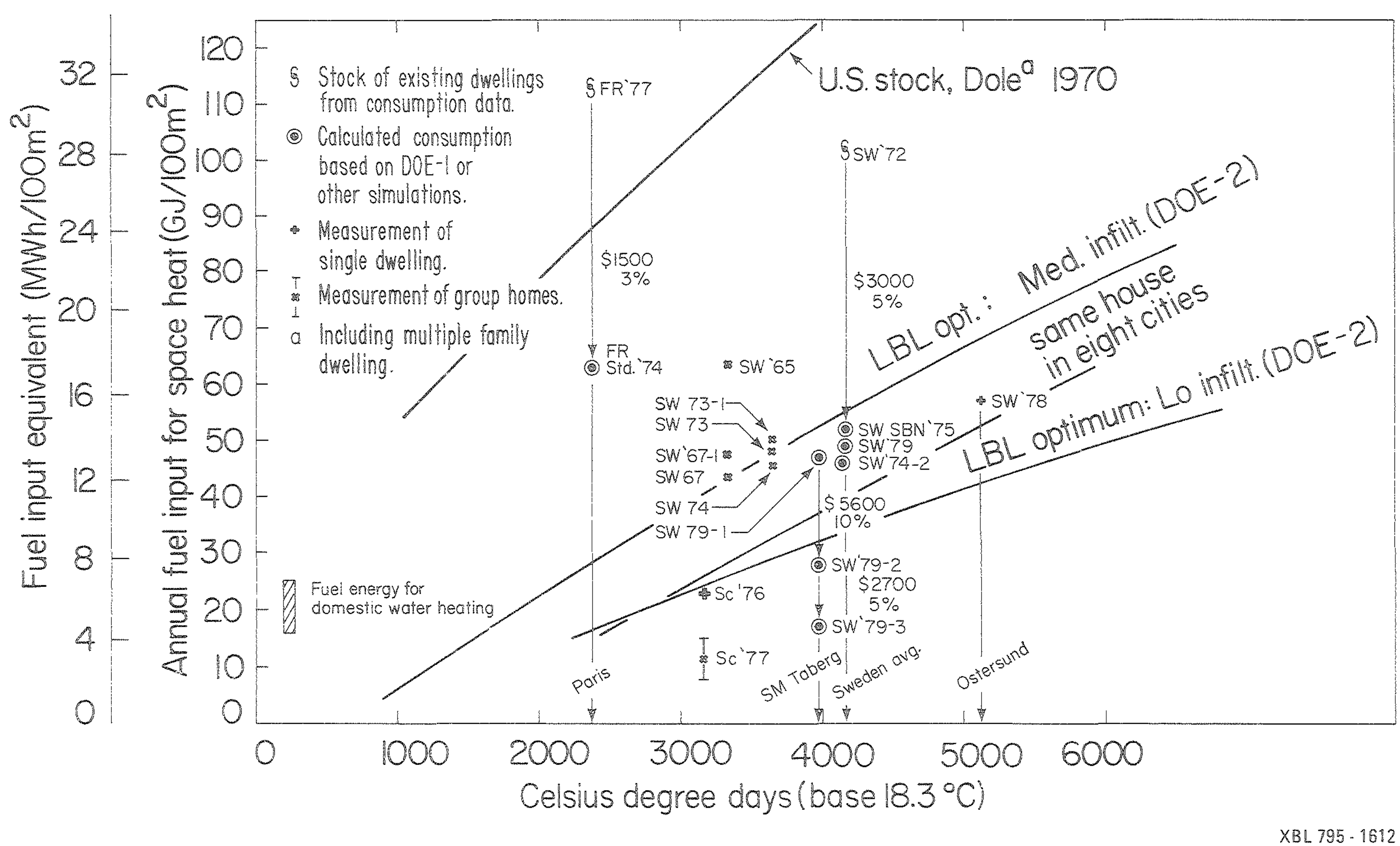
Fuel input equivalent (MWh/100m2)
Annual fuel input for space heat (GJ/100m2)
Celsius degree days (base 18.3 °C)
§ Stock of existing dwellings from consumption data.
⊚ Calculated consumption based on DOE-1 or other simulations.
Measurement of single dwelling.
Measurement of group homes.
a Including multiple family dwelling.
Fuel energy for domestic water heating
U.S. stock, Dole[a] 1970
§ FR`77
$1500 3%
FR Std.`74
SW`65
§ SW`72
$3000 5%
LBL opt.: Med. infilt. (DOE-2)
same house in eight cities
LBL optimum: Lo infilt. (DOE-2)
SW`78
SW 73-1
SW 73
SW`67-1
SW 67
SW 74
SW 79-1
SW SBN`75
SW`79
SW`74-2
$ 5600 10%
SW`79-2
$2700 5%
SW`79-3
Sc`76
Sc`77
Paris
SM Taberg
Sweden avg.
Ostersund
XBL 795 - 1612

Figure 1

Figure 2. Steady Drop in the Thermal transmission of walls and outer ceilings in Swedish dwellings, according to Riksbyggen, as given in EnergiprognosUtredningen, 1974 (Stockholm: Liberfoerlag). The great drops are associated with strengthened building codes. The X indicates the 1975 value for outer ceilings (attics) as prescribed in SNB 75. M_w and M_r give the Minnesota, U.S.A. values for walls and ceilings, respectively, according to 1978 building practices as analyzed by the Nat. Assn. of Home Builders. The primed Minnesota values are those recommended in the Building Energy Performance Standards Analysis carried out at LBL (See Federal Register, Part II, Dept. of Energy, Nov. 28, 1979).

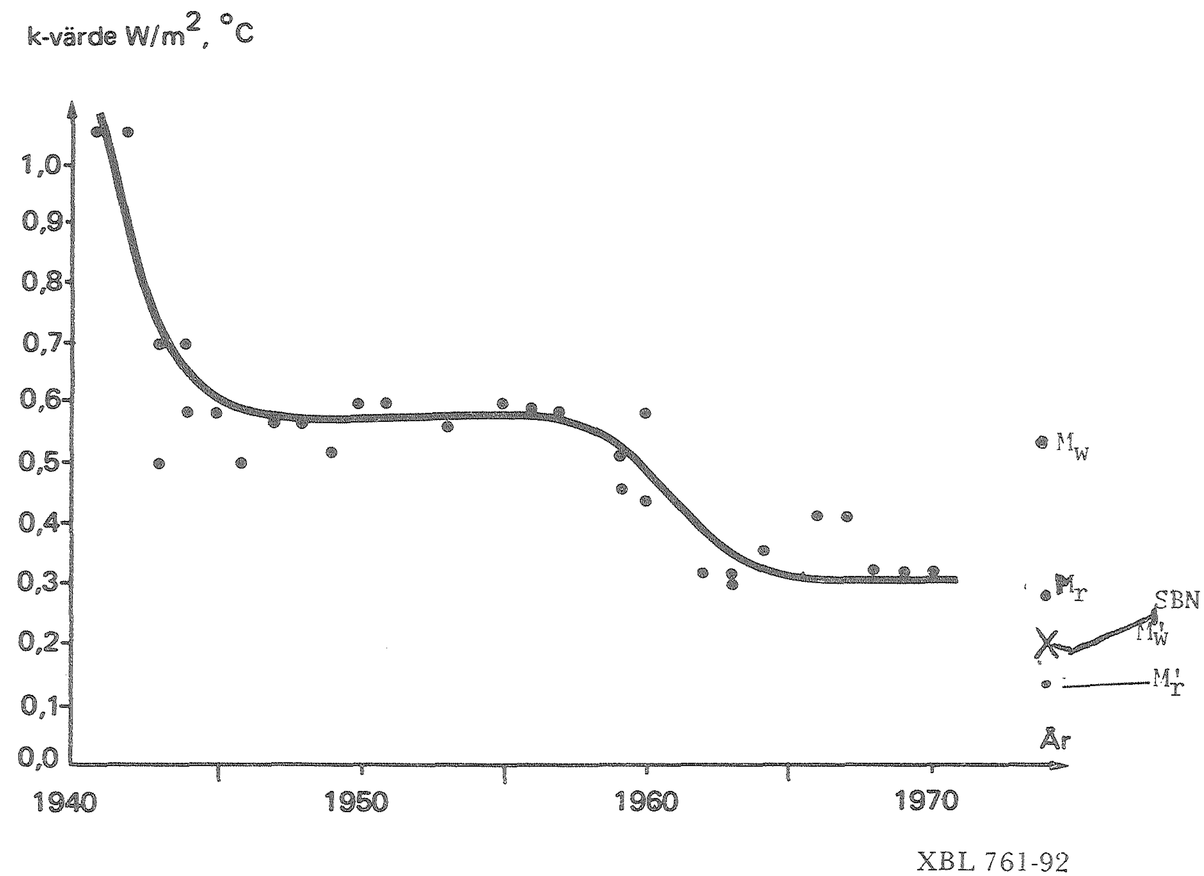
k-värde W/m2, °C
1,0
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0,0
1940
1950
1960
1970
År
Mw
Mr
SBN 75
M'w
M'r
XBL 761-92

Figure 2